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THE SCIENTIFIC CONFERENCE

"LEARNING AUTOMATIC MACHINES AND

INFORMATION PROCESSING IN ORGANISMS"

by A. V. Napalkov

- West Germany -

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THE SCIENTIFIC CONFERENCE "LEARNING AUTOMATIC MACHINES AND INFORMATION PROCESSING IN ORGANISMS"

[Following is a translation of an article by A. V. Napalkov in the Russian-language periodical Voprosy Psikhologii (Problems of Psychology), Vol. VIII, No. 1, Moscow, 1962, pp 168-173.]

I. Organization of the Conference; Participants and Program

The conference was held from 10 to 15 April in Karlsruhe (FRG) [West Germany], in the new physics building of the Polytechnic Institute. It was organized by the noted German scientist Doctor of Technical Sciences Professor K. Steinbuch, director of the recently established "Institute of Information Processing and Transmission." The conference was called under the auspices of the Institute. Noted scientists from Great Britain, United States, France, Switzerland, GDR [East Germany], FRG, and other countries, working in the area of cybernetics, took part; in particular:

1. Director of the Teddington Branch of the National Physics Laboratory, the noted cyberneticist Professor O. M. Attlee (Britain), and Doctor A. Andrew.

2. Director of Special Research at the Pittsburgh Polytechnic Institute, A. Newell (USA).

3. The noted cyberneticist, D. M. Mackey.

4. Director of the Special Research Program on Perception Systems, and director of the Aeronautics Laboratory at Cornell University in New York, Doctor F. Rosenblatt.

5. Docent at the Vienna Polytechnic Institute, Tsemanek.

6. Director of the Institute of Information Processing and Transmission, Professor K. Steinbuch.

7. Laboratory director Prof. Mittelstadt, and others.

In addition to the formal presentations, there were many unofficial discussions and talks, some of which had been planned beforehand. For example, the desire to meet in order to discuss scientific problems in the development of cybernetics had been expressed before the conference by Prof. Reitman of Prof. Newell's group in California, Dr. Rosenblatt (USA), Prof. Mackey (Britain), Dr. Andrew (Britain), Prof. Steinbuch (FRG), and Mittelstadt (FRG).

The main topic of the conference was the possibility of studying the principles of the operation of the brain and to create new cybernetic machines on that basis. Theoretical problems of learning, mechanisms of brain processes underlying complex problem solving and concept formation, perception of form, recognition of speech and written material, and laws of information processing in neural centers were discussed. Means of employing the principles of the functioning of the brain in the design of new cybernetic machines were examined, and reports were read on several models which embody these principles.

The orientation of the conference was reflected also in the complection of the body of participants. In attendance were nearly all leading scientists working on the investigation of the principles of the functioning of the brain in connection with problems in cybernetics (with the exception of U. Ross Ashby), together with mathematicians, physiologists, engineers, and psychologists.

On the other hand, scientific workers in the areas of technical cybernetics (computer technology, machine translation, automation, etc.) were not invited to the conference. These areas were not discussed.

The restricted character of the conference promoted a greater unity of work, and was justified in view of the independence which the problems discussed have acquired as a scientific field. The importance of the conference stems from the novelty of the problems examined and from the great promise which the field of research holds for technology and for the study of the brain.

In recent years, various scientists have opened up new

approaches to the development of automatic machines capable of learning, concept-formation, and problem solving. The talks and discussions made possible comparisons of these different approaches and points of view, discoveries of points of agreement and contention, and the setting of new directions.

An important characteristic of the conference was its close relatedness to the development of the doctrines of I. P. Pavlov on higher neural activity. One of the meetings (13 April 1961) was specifically concerned with conditioned reflexes. Many of the reports given on other days were also based on the work of I. P. Pavlov or on the applications of separate propositions of his system.

Before the formal opening of the meeting of 13 April, the chairman, Professor K. Kupfmuller (FRG) dwelled especially on the significance of Pavlov's work. He also expressed a high opinion of the work being done in the USSR at present in the application of basic propositions of the system to the solution of essential problems in cybernetics. This speech was met with the warm applause of the entire audience.

II. New Trends in Research

The conference is of great significance in that it defined several very important areas of research which do not fall into the categories of science which now exist (physiology, psychology, automation, mathematics, computer technology, etc.).

1. The Group of Prof. A. Newell.

The work of a group of American scientists (Newell, Shaw, Simon, Reitman, Feigenbaum, et al.) represents one of the most promising directions of research.

This group is conducting research on the principles of the operation of the brain which underlie the complex forms of its activity, particularly problem-solving.

This area was described in Prof. Newell's report "GPS, A Programmed Model of Human Problem-Solving." This report was also discussed informally. Research in complex brain processes is being done experimentally with human subjects -- students at the Institute of Technology.

A set of relatively simple brain processes (algorithms) is found. In order to establish whether such a collection of interacting rules in the functioning of the brain can serve as the basis for complex problem-solving behavior, a method of model-construction is employed. A computer is programmed with a complex set of rules. The ability of the computer to reproduce the brain's capabilities is then studied. An evaluation of the machine's behavior shows the precision and accuracy with which the cortical processes have been analyzed. If the computer does not solve problems as well as the human, the causes of this deficiency in performance are determined. An analysis of inadequacies in the machine's operation serves to furnish points of reference for further experimentation on humans to disclose the rules lacking in the model. In this manner, on one hand, new automatic machines are built, and on the other, the mechanisms of brain processes are being studied in great detail.

Certain important theoretical grounds for research in this area had been presented by A. Newell, I. K. Shaw, and Simon, in the paper "Elements of the Theory of Problem-Solving in Humans." These investigators emphasize that research in brain processes can be conducted on various levels and with different degrees of precision. The development of the research described above implies a level which the authors call the level of "informational processes." This means that the organism is considered as a system which is composed of receptors, effectors, and a control system. It is the control system which is being studied.

The elements studied are not the physical processes in nerve cells or neural networks, not the phenomena which fall into the categories of psychological events, but rather, "primitive informational processes." The chief task is to disclose discrete sets of rules for combining these primitive informational processes into complex programs.

With this research, it will be possible to expose mechanisms by which the brain operates in solving complex problems, and to show that a computer program is capable of solving the same problems.

Newell, Shaw and Simon point out that some scientists are frequently perplexed by the notion of a program of simple rules which underlies the complex brain activity associated with problem solving. However, it can be shown

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by means of computer-electronic models that a given set of
rules is indeed sufficient for the solution of a problem.

The research (Newell, Shaw, Simon, E. Feigenbaum, V.
Reitman) has produced certain important algorithms of
information processing, and a program, called the "General
Problem Solver" (GPS), was developed.

This program, when put into a computer, makes it
possible to solve problems with the computer, whereas this
is not possible without the program.

The program comprises two systems: 1) analysis of
means of reaching a goal, and 2) planning. The preliminary
stage of analysis of paths to the goal is an important
groundwork for choosing trial paths in the solving stage.

The methods of planning involve abstraction, through
the elimination of certain details of the initial objectives.
The problem is structured and solved in an abstract form.
A given solution is then translated into an elementary
form. Gradually, an optimum plan of solution is developed.
This plan may be successful, or it may not lead to the
solution. The investigators hope that the principles
which they discover will make possible an extention of the
creative abilities of machines.

It is important to note that the "General Problem
Solver" program allows efficient solutions to be reached
when there do not exist algorithms for the solution of a
problem and when only incomplete information is available.
In such cases, a solution is possible by virtue of a set of
rules for an efficient search for a solution (algorithms of
search). These search rules may embody criteria for the
most promising directions of search, the most efficient
order of examining the possible paths to a solution, and
for the exclusion of search patterns which cannot lead to
success.

A property of these methods of solutions is that they
do not always lead to success, and that the search may
continue for an indefinitely long time. The authors call
such methods "heuristic."

The new automatic machnies which are being created by
these investigators are finding a great variety of appli-
cation. For example, they are found to be able to solve
problems associated with changes in the operating procedures

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and routines of a factory being converted to produce a new type of machinery. In such a case, the computer determines the most nearly optimum utilization of the old equipment in combination with new equipment, the most effective sys-tem of conveyor handling, supply of materials, etc. Engineers, mathematicians, physiologists, and psychologists are taking part in the work of this group.

2. The Group Headed by Prof. K. Steinbuch
(Institute of Information Processing, Karlsruhe, FRG).

A new and important direction in the creation of cybernetic machines is being taken at the Institute, which is directed by Prof. K. Steinbuch. This area was described in several reports.

K. Steinbuch outlined the basic principles in a new approach to the creation of learning machines; these principles have been termed the "learning matrix."

The "learning matrix" is a new method of designing electronic information-processing systems. The method makes possible the modeling not only of single conditioned reflexes, but of systems of interrelated conditioned-reflex reactions. In the opinion of Prof. Steinbuch, this fulfills an important requirement in the construction of learning machines of new types, whereas single reflexes cannot be used as a basis for advanced systems of this nature.

The use of the learning matrix appears very promising. Automatic machines built on this principle have a number of very desirable characteristics, such as the ability to recognize complex forms and patterns of the environment, perform complex goal-directed actions, etc. More advanced automatic machines are constructed by using several learning matrices connected in a particular manner.

The embodiment of the principles of the generation of conditioned reflex systems in automatic machines is of great practical importance. A discussion of this subject was presented in the report given by a group of young researchers at the Institute of Information Processing which is directed by Prof. Steinbuch: V. Gorke, H. Kaumperkuak, and S. V. Wagner.

Learning machines of the above type find the following practical applications: 1) automatic recognition of signs

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and images, particularly for electronic computers capable of print recognition; 2) speech-recognition machines; 3) rapid information search, particularly for machines designed for work in libraries and archives; 4) control of industrial processes; 5) traffic control in transportation; 6) weather-forecasting; 7) automatic chemical analysis; 8) medical diagnostics, and others.

A number of technical problems connected with the building of such machines was brought to light in a report by H. Kraft and H. P. Hohnerloch.

An interesting film, illustrating the operation of an automatic machine, was shown.

The report of Dr. H. Frank, Head of the Psychophysiology Division at the Institute, was received with great interest. Dr. Frank examined the significance of the "learning matrix" for "informational psychology." The term "informational psychology" was proposed by H. Frank to define a new area in the study of the activity of the human brain; this area comprises research in which, in contrast with classical methods of psychology and physiology, the operation of the brain is analyzed with reference to basic principles of coding and processing of information. It employs information theory, theory of automatic control, and other theoretical aspects of cybernetics. The importance of such a new approach to the study of brain activity was substantiated by H. Frank in a series of previously published articles.

It is clear that the research of Newell's group, described earlier, together with many other investigations, must be considered to lie in this area of research. The area has been variously named physiological cybernetics, bionics, neurocybernetics. The most convenient and descriptive term has evidently not yet been found, but the importance of this research direction as a new independent division of science is becoming apparent.

The research being conducted at the Institute of Information Processing in Karlsruhe is of great fundamental significance.

K. Steinbuch outlined several new positions in learning theory. Steinbuch considers the learning process as the creation of an "internal model of the outside world." This implies that in the external world there are cause-and-

effect relationships and laws which have an objective
existence and which are unknown or only partly known to the
human or animal, and that an organism or a learning machine
must actively study its environment and discover appro-
priate relationships and regularities.

This point of view differs markedly from the behavior-
istic conception widespread in the United States, that the
learning process can be reduced to the statistics of suc-
cessful and unsuccessful actions.

As is known, the behavioristic conception is the basis
of the reactionary philosophic movement of pragmatism
(James, Dewey, Peirce). Pragmatism rests on the assertion
that it is uncharacteristic for the human or animal brain
to discover the objective laws of the environment, and
that the basic functioning of the brain is the attainment
of goals by a blind process of "trial and error." In
accordance with this conception, there has been a wide-
spread tendency to reduce the problem of the learning
machine to the statistical processing of successful and
unsuccessful trial acts and the increased probability of the
occurrence of acts which lead to the greatest relative
frequency of successes. Mathematical statistics and proba-
bility theory are employed.

In contrast with these views, K. Steinbuch asserts
that a learning machine will function properly only if it
constructs an internal model of the external world. This
point of view corresponds to the materialistic interpreta-
tion of the learning process made by I. M. Sechenov and I.
P. Pavlov, which is based, as is known, on the principle of
determinism. In the solution of problems associated with
the creation of new automatic machines, this conception
specifies an orientation in research which is different
from the orientation determined by behaviorism and prag-
matism.

In his publications ("Learning Automatic Machines,"
1959, and "The Learning Matrix," 1961) K. Steinbuch examines
principles and mechanisms which can yield a reliable and
precise "model of the external world." He discusses the
question regarding the properties of the control systems
and the nature of the conditions which are necessary for a
precise correspondence between the "model" and the real
external environment. Steinbuch also deals with means of
detecting a lack of good correspondence between the "model"
and the environment, and discusses mechanisms which lead

to the correction of such a condition. These considerations
are important for learning theory and for an understanding
of the principles of brain functions.

It should be noted that certain of Steinbuch's ideas
are very closely related to those being developed by
scientists in the USSR.

Steinbuch himself does not deny these close ties,
which he repeatedly emphasized in conversations, between
his work and the work being done in the Soviet Union.

Steinbuch emphasizes in particular the intimate con-
nections between his work and the teachings of I. P. Pavlov.
In mentioning the major scientific events which formed the
foundation for the new area of research, he puts the works
of Pavlov in first place ("Learning Automatic Machines,"
1959). In his other articles, Steinbuch devotes great
attention to the significance of these works. At the same
time, he points out that in the design of advanced auto-
matic machines it is insufficient to incorporate the prin-
ciples of the generation of single conditioned reflexes,
and that it is necessary to incorporate a large number of
interrelated reflexes in a complex system ("The Learning
Matrix," Cybernetics, 1961, p. 36).

This orientation enhances the similarity between the
work of Steinbuch and the research being done at Moscow
University.

The work described above was very successful. In two
years, a number of new automatic machines capable of concept-
formation and recognition of form has been built, on the
basis of principles different from those used by Rosenblatt.
Automatic machines which learn have been built and are
finding widespread practical application.

3. The Group Headed by Docent Zemanek
(Vienna Polytechnic Institute)

This group includes the young scientists V. Kudielka
and H. Kretz. The biological framework of the research
stems from the teachings of I. P. Pavlov and is also
related to the work of A. I. Angian and V. G. Walter. The
collaboration of Docent Zemanek and A. I. Angian led to the
development of an "objection-free" program for the functions
of learning systems.

In dealing with theoretical questions regarding learning systems the tools of mathematical logic were employed.

A number of programs was developed for the "Malluferl" computer. Experiments on this computer have led to the creation of models which more fully reflect all aspects of the generation of conditioned reflexes (the "extended model of the conditioned reflex"); the properties and capabilities of various learning systems are being studied.

The work of this group, begun in recent years, is very promising.

4. The Research of B. Gramer and F. Wenzel

The research described in the reports of B. Gramer and F. Wenzel (Darmstadt, FRG) is of great interest.

These researchers are engaged in experimental investigations, using human subjects, of the principles which the human brain utilizes in the recognition of words (reading a text) and sounds (listening to speech). It is known that the human does not perceive all of the letters in a word and all the words in a sentence. He understands the meaning of sentences from certain orienting-words. These orienting-words are the products of the individual's past experience, and allow him to read rapidly and to understand rapid speech. In order to create machines which are capable of recognizing speech and reading textual material, it is necessary to discover the means by which the human brain performs such acts. It was pointed out in discussions in the course of the conference that, unless such principles are known and applied, a machine will not be able to process properly the enormous quantity of information involved.

The reports of F. Wenzel and B. Gramer presented interesting methods and experimental data which mark the way to the solution of this problem and thus to rapid progress in the development of new techniques in automation.

5. The Report of A. Andrew

It is proper to dwell also on the work of Dr. A. Andrew (National Physics Laboratory at Teddington, England) who is already well known for his research in learning automatic machines.

Dr. Andrew has made an interesting attempt to disclose

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the principles of neural organization and functioning which underlie the learning process in animals. The subjects in the research were lower animals (worms, mollusks) in which the nervous system is very simple and quite accessible to scientific analysis. An electrophysiological method was employed. However, this research is essentially different from ordinary electrophysiological work with respect to its aims and methods of analysis. The research task was to solve problems associated with theory of the nervous system and with other problems of cybernetics.

While electrophysiologists are concerned with the analysis of bioelectrical phenomena per se, the research of the author is directed toward the disclosure of the actual mechanisms of learning. This is a very difficult, and at the same time an important problem area. It is of importance for physiology as well as for the development of learning machines. As Dr. Andrew himself pointed out in discussions, his investigations are not yet complete. Nevertheless, the promising nature of the work is evident even at its present stage.

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The report of Mackey (Great Britain), Attlee (Great Britain), and Rosenblatt (USA) elicited great interest. The publications of these authors have been translated into Russian, and therefore the writer will not discuss in great detail the very promising areas of research which have emerged.

A number of very interesting reports was devoted to the analysis of various problems in learning theory and to the description of working models of learning automatic machines. H. Harmes (FRG) examines the role of probability in the learning process. H. Remus describes experiments in setting up various learning programs on the IBM 704 computer.

H. Hartl (FRG) outlines learning-machine programs which solve various technical problems. These programs were developed in accordance with Steinbuch's conception of learning as the creation of an "internal model" of the external world.

The report of R. Aler (Austria) describes research on a model for learning in a maze.

A great body of work is devoted to the study of processes of control, regulation, and information processing in living organisms.

The application of recent advances in cybernetics will contribute a great amount to the solution of this problem. It may be expected that progress in this area will be accompanied in the near future by new and significant achievements in medicine. There are cogent reasons to believe that the growth of many diseases, hypertonic disorders, breast cancer, bronchial asthma, etc. is associated with the disruption of regulatory processes in the organism. Knowledge of the mechanisms of the regulation of the functions of internal organs, which appears to be attainable by virtue of the current state of cybernetics, therefore assumes a primary importance.

Two conferences have already been held in Germany on these new areas in science. The work of Mittelstadt, Holst, Kunfmuller, and others, is widely known. Reports presented at the conference reflected further developments in the area.

The report of Feldtneller dealt with basic problems concerning the interaction of physiology, psychology, and information-processing theory.

The comprehensive reports of K. Kupfmuller, V. Ernst-hausen, Schwartzkopf, and G. Baumgartner described experimental data and theoretical work associated with analysis of information processing and information coding in nerve cells and neural centers in the brain. This new approach to the study of the functioning of the nervous system is of great interest. It is known that the processing and transmittal of information is the basis of the operation of the brain. Nevertheless, these processes until recently remained outside the pale of physiology, and despite the existence of an enormous amount of "factual information" the basic mechanisms underlying the complex functions of the brain are still not clear.

A series of reports was devoted to the analysis of the mechanisms of vision and audition within the framework of contemporary cybernetics. Reports by Mittelstadt, G. Vossius, and others described an analysis of the mechanisms of coordination in complex motor reactions in animals.

A familiarity with all of this research is very

important, since this area, which is promising for patho-physiology and medicine, has until recently not been adequately explored in this country.

Although a great number of institutes are working in physiology, patho-physiology, and experimental medicine, work in the area is not discussed at scientific meetings and conferences here. Physiological journals do not publish such research. This circumstance is especially odd in view of the fact that the teachings of I. P. Pavlov are closely related to the study of regulatory processes in the organism, and that Pavlov always welcomed new possibilities of studying regulatory mechanisms.

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